UDC 666.1.022:666.127.001.24

ACCOUNT OF CULLET COMPOSITION IN CALCULATION OF BATCH FORMULAS

M. M. Khaimovich[1]

Translated from Steklo i Keramika, No. 12, pp. 20 – 21, December, 2005.

Methods for solving the problem of taking into account the oxide composition of cullet in calculating a glass batch formula are analyzed. An approach to solving this problem consistent with the program for batch formula calculation is described.

The desire of glass container manufacturers to lower production cost has led to a substantial increase in the amount of cullet introduced into a glass batch. However, the growing output of acceptable product, which is always the ultimate goal of manufacturers, results in a decreasing amount of waste glass cullet. This forces manufacturers to increase the share of purchased cullet.

Such an approach decreases production cost and is widely used abroad. However, when a large amount of cullet is added, it is more difficult to maintain the quality of glass, since outside cullet is heterogeneous and its chemical composition, in contrast to locally generated cullet, does not coincide with the desired glass composition.

In order to ensure high quality of glass, outside cullet has to undergo treatment: it should be purified from impurities, crushed, and screened according to its granulometric composition and color. However, even high-quality pretreatment or using cullet from a single supplier does not eliminate the problem of taking into account the oxide composition of cullet in calculating the batch formula. This problem is not so simple as appears at first glance and there are two approaches to its solution.

The first simplified solution consists in estimating the composition of glass that is to be obtained by adding to a batch of a prescribed composition a certain quantity of cullet with a known oxide composition. Such a problem is rather easy to solve. If only one type of cullet is added, the glass composition can be determined by the following formula:

$$R_i = \frac{S_i\,(100 - P) + T_i P}{100}, \tag{1}$$

where R_i is the content of the ith oxide in glass obtained after adding cullet, %; S_i is the content of the ith oxide in glass obtained from the batch, %; T_i is the content of the ith oxide in the cullet that is being added %; P is the share of glass melted from the cullet in the total quantity of glass melted, %.

Some factories add several types of cullet to the batch: usually local and externally purchased cullet and sometimes cullet purchased from various suppliers. Each type of cullet has it own oxide composition. In this case the formula takes the following form:

$$R_i = \frac{S_i\,(100 - P_1 - P_2 - ... - P_k)}{100} + \frac{T_1^i P_1 + T_2^i P_2 + ... + T_k^i P_k}{100}, \tag{2}$$

where T_k^i is the content of the ith oxide in the kth type of introduced cullet, %; P_k is the share of glass melted from the kth type of cullet in the total quantity of glass, %; in this case always $P_1 + P_2 + ... + P_k < 100\%$.

However, the other approach is more interesting for practical purposes. It consists in calculating the formula of the batch that has to be mixed with one or several types of cullet in order to produce a desired glass composition.

Let us consider solving this problem using a single type of cullet. At the first stage, considering the required glass composition, the composition of the cullet added, and the ratio between the glass melted from the batch and from the cullet, we determine the oxide composition of glass Z that should be produced from the pure batch (without cullet). For this purpose we use the following formula:

$$Z_i = \frac{X_i \times 100 - T_i P}{100 - P}, \tag{3}$$

where Z_i is the content of the ith oxide in glass that can be melted from pure batch (without cullet), %; X_i is the required content of the ith oxide in glass, %; T_i is the content of the ith oxide in cullet, %.

[1] Stromizmeritel’ Joint-Stock Company, Nizhny Novgorod, Russia.

At the second stage we calculate the formula of the batch that can produce glass with the oxide composition Z.

At the third stage, based on formula (1) we calculate the real composition of glass that can be obtained from the calculated batch formula and added cullet, taking into account errors in calculating the batch formula.

If several types of cullet are added to the batch, in order to determine the oxide composition of glass Z that has to be produced from pure batch (without cullet), then instead of formula (3) at the first stage we use the following formula:

$$Z_i = \frac{X_i \times 100 - T_1^i P_1 - T_2^i P_2 - \ldots - T_k^i P_k}{100 - P_1 - P_2 - \ldots - P_k}. \tag{4}$$

Then at the third stage, instead of formula (1) we use formula (2) for calculation.

To automate solution of the considered problems, the program for batch formula calculation developed at the Stromizmeritel' Company [1] has options for carrying out the above described calculations.

The previous versions of the program had the option for calculating the quantity of cullet that has to be added to the batch, if the percent ratio between the batch and the cullet is specified in additional calculations performed after the end of the batch formula calculation. In the latest version, the quantity of cullet to be added is specified as percentage of glass melted from the cullet. We have also developed an additional program for converting the percent ratio of batch to cullet into a percent ratio of glass melted from the batch to glass melted from the cullet (considering the batch melting loss).

This conversion is performed according to the formula

$$P = \frac{100Y}{Y + (100 - Y)\left(1 - \dfrac{U}{100}\right)}, \tag{5}$$

where Y is the share of cullet in the total amount of batch and all kinds of cullet, %; U is the batch melting loss, %.

It is assumed in formula (5) that the quantity of glass melted from the cullet is equal to the quantity of the cullet and the quantity of glass B melted from W kg of the batch is determined as follows:

$$B = W\left(1 - \frac{U}{100}\right).$$

To solve the first of the considered problems, in the batch formula calculation program one has to specify an additional formula for the cullet (with the calculation type equal "in relation to the glass melted from the batch") and the line "cullet" should be included in the list of main materials, specifying its oxide composition. In this case the quantity of cullet for melting is calculated and the results indicate not only the glass composition, for which the batch formula is calculated, but also the composition of glass that will be produced after adding cullet.

To solve the second problem, it is possible to specify the content (in percent) of cullet in the preliminary calculation formula. The preliminary calculation formulas in the previous versions of the program were used to determine the quantity of sulfate specified via the content of alkalis introduced or the quantity of the second kind of sand (if the batch uses several kinds of sand). However, in these cases a particular oxide was indicated for the material (Na_2O for sulfate and SiO_2 for sand) and the quantity of material was calculated on the basis of this oxide. With respect to cullet, one should specify in the preliminary formula that the calculation is performed for "ALL" oxides. The oxide composition of cullet is given in the main table, similarly to other materials participating in preliminary calculation. Before the batch formula calculation, a calculation is performed using formula (3) or (4) and then for the other materials indicated in preliminary calculations. After the end of preliminary calculations, a batch formula for the corrected glass composition is determined.

Finally, the program determines the composition of a batch which, together with the specified percent of cullet of the specified oxide composition, will produce the required glass.

The table of results gives the batch calculation data and the composition of glass to be produced from the batch, as well as the total chemical composition of glass determined by formulas (1) or (2). It should be note that in this case as well the content of added cullet should be given based on total melted glass.

The above described upgrade of the batch formula calculation program makes it possible to simplify calculations related to adding cullet whose oxide composition differs from that of the glass melt in the furnace. Using these calculations, one should not forget that their accuracy depends on the accuracy of initial data. It should be taken into account that the stability of the parameters of purchased glass cullet can be guaranteed only if it is the waste of a single production process.

The proposed calculation methods can be used not only to account for the composition of cullet but also to account for the dissolution of furnace refractories.

REFERENCES

1. M. M. Khaimovich and K. Yu. Subbotin, "Automation of batch formula calculation," *Steklo Keram.*, No. 4, 27 – 30 (2005).